

LIBRARY  
RESEARCH REPORTS DIVISION  
NAVAL POSTGRADUATE SCHOOL  
MONTEREY, CALIFORNIA 93940

NPS-61-82-003-PR

# NAVAL POSTGRADUATE SCHOOL

## Monterey, California



### SUMMARY OF WORK ON ACOUSTIC PROPERTIES OF UNDERWATER BUBBLE SCREENS

O.B. WILSON and J.V. SANDERS--  
Department of Physics and Chemistry

FINAL REPORT FOR PERIOD JAN 1981 - DEC 1982

Prepared for:

Commander, Puget Sound Naval Shipyard

ATTN: Mr. John Kriebel, Acoustic Range Branch, Code 246  
Bremerton, WA 98314

NAVAL POSTGRADUATE SCHOOL  
Monterey, California

Rear Admiral J. J. Ekelund  
Superintendent

D. A. Schradly  
Acting Provost

This report was prepared as a summary of work supported in part by funds from the Puget Sound Naval Shipyard, Job Number N 0025181 WR 10124, dated 30 January 1981.

Reproduction of all or part of this report is authorized.

This report was prepared by:

## A. INTRODUCTION

The objective of this report is to summarize the work carried out this last year by Lieutenants Kelley and Marr as part of their thesis research, supported in part by funds from your organization, and to provide some comments, conclusions and recommendations of our own. The theses (1,2) have been transmitted separately.

In the design of an acoustically insulating bubble screen, there are many aspects which must be considered. The work of Kelley and Marr addressed primarily only two, the acoustic transmission properties of the screen and the noise which is generated by the screen itself.

## B. NOISE GENERATION

A possible problem in the use of a bubble screen for noise isolation is the noise generated by the screen. The work of LT Kelley (1) was directed toward the measurement of the noise power associated with the formation of a bubble screen. The following summarizes some of the results in Kelley's thesis and recasts some of the results in a form which may be more useful. Some errors noted in Ref. 1 are also corrected.

The work was carried out in the tanks in the Postgraduate School's Underwater Acoustics Laboratory, using a reverberant field method. The steady state spatial average of the sound level in an enclosure which has at least partially reflective walls is a measure of the acoustic power generated by a source in the enclosure. An enclosure, in this case, the tanks, and the associated hydrophone system were calibrated by using a source

of known power output. A similar averaging taken when an unknown source is in the enclosure can be used with the calibrations to estimate the power output from the unknown source. In this way LT Kelley was able to make some measurements of the acoustic power created or associated with the bubble screen for several configurations of bubble generating manifolds and air flow rates. Efforts were made to approximate bubble densities which might be appropriate for a screen which would be effective at the low acoustic frequencies of interest at Carr Inlet. Noise measurements were made on three different bubble generators, constructed by drilling rows of small holes in two inch diameter PVC pipe. They differed in number and sizes of holes. One had many small holes, the second had about the same hole area achieved by a smaller number of larger holes. The third had one row of small holes. The generator pipes were a bit less than five feet long and were located at the bottom of the tanks which are about seven feet deep.

Flow rates were controlled by valves and were measured using flow meters and by timed capture of air of a known volume from the bubbles. Only approximate estimates of bubble size were possible using visual and photographic observation. Bubble density was estimated from flow rates, bubble rise times and screen dimensions. Tests were conducted to discriminate between the relative noise generating characteristic of bubble formation, bubble rise and bubble venting. There were found some errors and omissions in Kelley's thesis. Some are trivial and obvious, but

the errors in Table VI are not. Enclosed as an appendix is a corrected Table VI with additional information tabulated.

Kelley's results support the following conclusions:

(1) The dominant source of noise from the screens produced in this lab is the bubble formation. Bubble migration appears to be a measurable source and may contribute as much as ten percent of the energy. Bubble venting appears to contribute very little additional noise in the frequency range we used (20Hz to 10kHz).

(2) The production of bubbles by a large number of small holes is significantly quieter (the order of 10 to 15 dB at some frequencies) than when the same air flow rate passes through a smaller number of larger holes. This effect may be due, in part, to better acoustic shielding provided by the bubble distributions around the pipe in the case of the larger number of holes.

Quantitative measures of the differences are imprecise because at many frequencies, the noise generated by the quiet screen was less than the ambient threshold of the measuring system.

(3) Figures 15 and 16 in Ref. 1, give the source level in one-third octave bands for the 4.8 foot long screen in dB ref 1  $\mu$ Pa at 1 meter. It can be seen that for the quieter type bubble generator, the source level determination is limited by the ambient noise threshold. We believe that the peaks in the output from the noisier manifold may be due to bubble resonances. However, we can not be really sure that these results would be applicable to bubble generators at significantly greater depths.

A worst case is from Figure 16 at 200Hz. The one-third octave source level given is about 132 dB. If it is assumed that



the acoustic power is a linear function of the length of the manifold and that the spectrum is uniform over a one-third octave band, then for one yard length of screen an acoustic power generated in a one Hertz band at 200Hz is about two microwatts. This is for a bubble screen about ten inches thick, one yard long with an air bubble concentration of about one percent and a total air flow rate of about 4 SCFM. The quieter screen should be less noisy than this by a factor of ten or more in sound power.

If one desired to predict the level at some distance from such a screen, a reasonable source model is to assume that the screen generator behaves as a line array of incoherent sources. Transmission loss models appropriate to the geometry of the problem would have to be chosen and applied.

#### C. ACOUSTIC TRANSMISSION

LT Marr (2) assumed a geometrically ideal screen (plane, parallel boundaries) with a uniform distribution of non-resonant bubbles having diameters much less than the wavelength of the sound. His computer calculations showed that for realistically obtainable bubble concentrations (between  $10^{-1}$  and  $10^{-3}$  volume percentage of air), stop bands exist within which the transmitted intensity is significantly reduced for a broad band of frequencies and a considerable range of incident angles. The attenuation in these stop bands exceeds 20 dB. Pass bands of nearly 0 dB attenuation have very small frequency extent.

A real bubble screen is not expected to be geometrically ideal nor is it expected that the bubble concentration will be uniform. The screen will increase in width as it rises to the

surface, and its boundaries will be irregular and ill defined. Furthermore, the bubble concentration will vary with depth (because of both the increased size of the individual bubbles and the increased width of the screen) and with distance from the axis of the screen. The first effect is difficult to predict because, while the bubble size as a function of depth is well known, the width of the screen has never been measured except for screens a few meters deep. The behavior of bubble concentration with distance from the axis is completely unknown; it has been reported in the literature that both the concentration and the bubble size decrease near the edges of the screen.

It is difficult to predict the effectiveness of a non-ideal screen. While the transmission in the pass bands will undoubtedly be reduced, it is equally likely that the transmission in the stop bands will be increased, making quantitative prediction of the effectiveness of a real screen impossible. Given the distribution of bubble concentration, sophisticated theoretical approaches exist that could be used to predict the transmission. However, it is our belief that the hydrodynamic theory necessary to predict the bubble concentration for a given bubble-injection population does not exist.

#### D. RECOMMENDATIONS

We believe that the work we have studied so far does not provide enough information to permit design and construction of a full scale bubble screen with a satisfactory degree of risk. This applies to both the noise generation and the attenuation. There is no question that a screen of the kinds considered by Marr would

provide a sizeable amount of attenuation. It is not really clear that the bubble generation noise would be a problem. We just do not yet have sufficient confidence to design a full scale screen.

It is our opinion that in the absence of a full-scale basic research effort the effectiveness of a real bubble screen would be most efficiently determined from in situ experiments. Such experiments must be carried out on a larger scale than those done previously where the screen depth never exceeded more than a few meters. Measurements would have to be made of the bubble concentration as a function of depth and distance from the axis of the screen. Acoustical transmission measurements should be made concurrently to allow comparison with theoretical results. Some very recent bubble screen experiments done in a pond by S.N. Domenico at Amaco Production Co.<sup>(3)</sup> came to our attention this week. We have talked with the author and expect to get a preprint of his paper soon. We will send a copy of it as soon as we get it.

We recommend that full-scale bubble screen experiments not be carried out until after more research has been done to better define the basic hydrodynamic properties of such screens. Since such work would be both expensive and slow, we suggest that other approaches to reducing the effects of noise interference in Carr Inlet be examined. Signal processing combined with directional hydrophone arrays might be a productive approach.



## References

1. Experimental Study of Noise Produced by an Underwater Acoustic Bubble Screen, Clark Thomas Kelley, MS Thesis, NPS, June 1981.
2. On the Design of an Acoustically Isolating Bubble Screen For Carr Inlet Acoustic Range, Kenneth William Marr, MS Thesis, NPS, June 1981.
3. Acoustic Wave Propagation in Air Bubble Screens in Water, S.N. Domenico, Paper presented at the October 1981 meeting of The Society of Exploration Geophysics. (To be published in Geophysics, 1982.)

TABLE VI. Bubble Screen Characteristics Data (Revised)

Test No.	Rise Time (Still) (sec)	Rise Time (Turbulent) (sec)	Glass Box Fill Time (min)	Screen Thickness (cm)	Estimated Bubble Radius (cm)	Air Flow Rates Ft <sup>3</sup> /min	Estimated Concentration (Ratio by volume of air to water) (percent)	
1	7.0	58	4.4	92	3.7	10	2.1	1.4
2	6.1	66	4.0	101	1.7	15	4.6	1.9
3	5.7	71	3.9	104	1.4	20	5.6	1.7
4	4.5	90	2.5	162	3.2	17	2.5	0.57
5	3.9	104	2.4	170	1.4	25	5.6	0.83
6	3.7	110	2.4	170	0.9	27	8.7	1.2
7	7.0	58	5.3	77	9.4*	7	0.4	0.47
8	6.6	61	5.0	81	7.8	7	1.0	1.1
9	6.3	64	5.0	81	6.3	8	1.2	1.2

\* Glass box turned lengthwise to reduce fill time.

# DISTRIBUTION LIST

Commander Puget Sound Naval Shipyard ATTN: Mr. John Kriebel Code 246 Bremerton, WA 98314	2
Dudley Knox Library Naval Postgraduate School Monterey, CA 93940	2
Professor J.V. Sanders Code 61Sd Naval Postgraduate School Monterey, CA 93940	1
Professor O.B. Wilson, Jr. Code 61Wl Naval Postgraduate School Monterey, CA 93940	1
LT Kenneth Marr 4717 Thresher Ct. Virginia Beach, VA 23464	1
LT Clark Kelley 1812 Long Meadow Dr. Montgomery, AL 36106	1

U200022





DUDLEY KNOX LIBRARY - RESEARCH REPORTS



5 6853 01071516 2

U200022